

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 December 2001 (27.12.2001)

PCT

(10) International Publication Number
WO 01/98100 A1

(51) International Patent Classification?: B60K 17/344,
F16H 1/22

(21) International Application Number: PCT/GB01/02667

(22) International Filing Date: 15 June 2001 (15.06.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0015115.9 20 June 2000 (20.06.2000) GB

(71) Applicant (for all designated States except US): **WOR-
RALL, Trevor, James** [GB/GB]; Radical Power Transmis-
sion, 14 Sussex Street, London SW1V 4RS (GB).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **PENGILLY, Eric,
Alexander** [GB/GB]; Radical Power Transmission, 14
Sussex Street, London SW1V 4RS (GB).

(74) Agent: **PHILLIPS & LEIGH**; 5 Pemberton Row, London
EC4A 3BA (GB).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK,
SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA,
ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,
IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,
CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

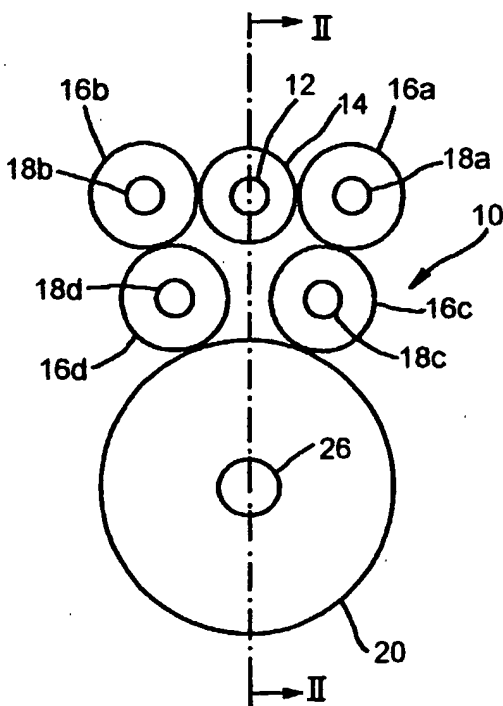
- of inventorship (Rule 4.17(iv)) for US only
- of inventorship (Rule 4.17(iv)) for US only

Published:

- with international search report

[Continued on next page]

(54) Title: GEARED TRANSMISSIONS



(57) Abstract: A gear assembly (10) for transmitting torque between an input rotatable member (12) and an output rotatable member e.g. differential unit (24) comprises an input gear (14) rotatable with the input member (12), an output gear (20) rotatable with the output member (24), and intermediate gears (16a, 16b, 16c, 16d) held simultaneously in mesh with the input gear (14) and output gear (20). Various arrangements are disclosed for sharing the transmitted torque evenly between the paths provided by gears (16a, 16b, 16c, 16d). The transmission may provide a reduction ratio and is connected to a low reduction ratio differential gearbox of small size and slim profile.

WO 01/98100 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

GEARED TRANSMISSIONS

This invention relates to transfer gearing for transmitting power between first and second members rotating about parallel axes in automotive transmissions, for example in which power from the output shaft of a main gearbox must be transmitted to a pair of propeller shafts respectively extending fore and aft of the vehicle. These propeller shafts are usually interconnected by differential gearing, and extend generally parallel to the main variable ratio gearbox output shaft. Typically, power is transmitted between a gear on the main gearbox output shaft and a similarly sized differential gear, to give an approximate 1:1 gear ratio. There are other instances where power must be transmitted from a first shaft to a second, generally parallel shaft in an automotive transmission.

In heavy vehicles such as trucks, this power transmission is often via an intermediate gear supported on a layshaft of a transfer gearbox. The diameter and/or lateral offset of the intermediate gear may be selected to provide the required centre spacing between the parallel shafts. Where a large centre spacing is required, the intermediate gear diameter must be made correspondingly large. As the maximum transmissible torque depends mainly upon the load per unit tooth width, the intermediate gear and the co-operating gears must each be made relatively wide for transmission of high torque loads.

High torque loads and large centre spacings thus lead to a large and heavy gear train between the main and transfer gearboxes. Large diameter gears have a higher pitch line velocity and hence tend to be noisier in operation than smaller gears.

25

For lighter 4 x 4 "sports utility" vehicles, such transfer boxes virtually all use chain drives for power transmission between the parallel shafts. The driveline must operate at high RPM and because of the necessary gear diameter / operating centre distances a conventional single power path geared drive as used in trucks, for example, would involve unacceptably large gears and pitch line velocities. At the speeds concerned, chain drive has proven quieter than even precision ground gears and allows a more compact casing. However chain drives suffer from overheating problems and excessive centrifugal

loadings if used at speeds above about 6000 RPM. Their power transmission capacity is therefore limited.

Theoretically, an alternative design approach would be to provide a pair of intermediate
5 gears offset to either side of the plane containing the parallel shaft axes, these
intermediate gears each meshing simultaneously with corresponding gears on the parallel
shafts (e.g. in the main and differential gearboxes respectively). Assuming that all four
such gears are perfectly concentric, with perfect tooth pitches and profiles, supported on
shafts perfectly spaced relative to one another, journalled in perfect, play-free bearings,
10 the whole being made from perfectly inelastic materials, the transmitted torque will be
shared equally between the two intermediate gears, to provide parallel torque transmission
paths. The intermediate gears and the co-operating gears in the main and differential
gearboxes could thus theoretically be made correspondingly smaller and lighter.

15 However, commercially manufactured gearboxes are not perfect. The kinematic forces
acting on the intermediate gears coupled with the elasticity of the materials of the gear
assemblies means that in reality one of the intermediate gears tends to be forced inwards
towards the plane of the input/output shafts, whilst the other intermediate gear tends to be
forced outwards away from that plane. The intermediate gear forced inwards experiences
20 a higher torque than the intermediate gear forced outwards.

Furthermore, dimensional inaccuracies in the various gearbox components means that in
reality one of the intermediate gears will, when torque is applied, assume flank-to-flank
drive contact with each of the two adjacent gears, whilst at that instant the opposite
25 intermediate gear has not established drive contact. Thus at that time only one torque
transmission path is effective. As the torque load increases, provided that dimensional
inaccuracies are within acceptable limits, gearbox components will deform under load
until mutual drive contact is established between all adjacent gears. However, torque
sharing between the two transmission paths will be unequal, with the degree of inequality
30 corresponding to the size of the dimensional inaccuracies. The proportion of the torque

transmitted through each path may vary throughout the rotation cycle of the gearbox assembly, as the dimensional inaccuracies of each gear may vary cyclically.

Studies by NASA on helicopter gearboxes (see paper by Timothy L. Krantz "A Method to
5 Analyze and Optimize the Load Sharing of Split-Path Transmissions", published in
Design Engineering, vol. 88, Power Transmission and Gearing Conference ASME 1996,
at pages 227-242) have shown that satisfactory torque sharing between two parallel
transmission paths can be achieved if tooth flank position errors are controlled to less than
0.0005 radian. Under these conditions, the inequality of torque transmission might not
10 vary beyond, say, 60:40, leading to worthwhile savings in gearbox size and weight. Such
dimensional accuracy is achievable, certainly in aerospace and similar specialist
applications where high manufacturing costs are not prohibitive. However the
requirement for high dimensional accuracy means that such torque sharing arrangements
are impractical for mass produced automotive gearboxes, where low cost is an important
15 factor.

US patent no. 6035956 discloses an axle for low platform town buses in which hub
reduction gear trains are connected, one on each side, between the axle differential and
respective offset stub axles carrying the bus road wheels. Each transfer gear train
20 comprises a pair of intermediate gears providing parallel power transmission paths. An
input gear fixed to a respective output shaft of the differential meshes with both
intermediate gears simultaneously and is vertically movable so as to share torque evenly
between the power transmission paths.

25 It has now been realised that plural power path arrangements incorporating even torque
sharing capability are of significant benefit to transfer gearing elsewhere in automotive
transmissions, in particular between the main variable ratio gearbox and the axle
(differential) drive, and also in other locations "up stream" of the axle differential.

30 In accordance with the invention there is provided an automotive transmission comprising
a transfer gear train for transmitting torque between an input rotatable member and an

output rotatable member rotating about substantially parallel axes, the transfer gear train comprising an input gear rotatable with the input member, an output gear rotatable with the output member, and a pair of intermediate gears each held simultaneously in mesh with the input gear and transmitting torque to the output gear to provide two power
5 transmission paths,

characterised in that the output member drives differential gearing arranged to distribute driving torque to a pair of ground engaging wheels. Preferably, one of the gears in the transfer train is made movable in response to the transmitted torque so as to even out power transmission between the two paths. However such torque sharing can also be
10 achieved by other means, such as by controlling gear tooth flank position errors to within acceptably low limits.

The input gear is preferably made smaller than the output gear so that the transfer gear train provides a reduction ratio. The differential gearing may therefore have a lower
15 reduction ratio, even substantially 1:1. This enables it to be made considerably smaller and lighter. Pitch line velocities in the transfer gearing and in the rest of the transmission driven by it are also reduced, giving quieter operation. The sizes of the gears in the transfer gear train and differential can be smaller than in a conventional single power path driveline, which much reduces gear weight (roughly proportional to diameter squared) and
20 very much reduces gear moments of inertia (roughly proportional to diameter cubed).

In current driveline designs for passenger cars, the axle bevel gear has a large diameter, typically providing a reduction ratio of about 3:1 – even larger for heavy vehicles. Any diminution in this reduction ratio increases gear loadings “up stream”, including in the
25 main gearbox and transfer gearbox (if present). Current driveline proportions therefore represent a trade off between minimum gearbox size and maximum acceptable axle ratio. The plural power path transfer gear train of the present invention provides a high capacity, compact power transfer path that can handle the higher torque loads arising from the use of low ratio axle differentials, and may itself be used to provide a reduction ratio, thereby
30 reducing torque loadings on the main gearbox.

A smaller axle differential gives a greater ground clearance, which is important in off-road vehicles. Incorporating speed reduction in the transfer gear train also enables the overall reduction ratio of the transmission to be maintained, whilst using a smaller reduction ratio at the differential gearbox. This is beneficial in high performance vehicles such as racing cars, with engines operating at high RPM and which therefore require a high overall driveline reduction ratio. For such applications, the transfer gear train of the present invention again gives lower pitch line velocities and smaller, lighter, quieter, lower inertia differential gearboxes and final drivelines.

10 The two power paths enable the transfer gear train to be made smaller and lighter than a conventional transfer gearbox of equivalent duty. To facilitate assembly of the various gears in proper meshing engagement and to provide flexibility in the available gear ratios and in the centre spacing between the input and output members, a further intermediate gear is preferably provided in each power transmission path.

15

The torque responsive movement referred to above may for example be of the input gear. In one possible arrangement, the input shaft and the rotational axes of the co-operating intermediate gears all lie substantially in a common plane.

20 Where the various gears are spur gears, the input shaft may be made free to move (e.g. pivot) very slightly away from this plane. Then, when there is flank to flank contact between the teeth of the input gear and only one of the intermediate gears, the torque applied to the input shaft and the reaction at the contacting tooth flanks will form a couple causing the input shaft to move out of the common plane. This movement continues until
25 there is flank to flank contact at the other intermediate gear as well. Even torque sharing between the two power transmission paths is therefore achieved.

Where the various gears are single helical gears, the input gear may be free to pivot about an axis normal to the common plane. Out-of-balance forces acting in the direction of the
30 input shaft axis and arising from uneven torque sharing between the two power paths will rotate the input gear about the pivot axis in a direction tending to reduce the out-of-

balance forces, and hence evening up the torque sharing. Operation of such a mechanism is more fully explained in GB 1434928. To reduce or substantially eliminate thrust loads on the gear shafts, the gears may be mounted to their shafts by helical splined connections, the helix being of the same hand and having the same lead as the gear teeth.

5 The splined connection may itself allow the input gear to pivot about an axis passing through the input gear.

Similar arrangements are possible in which even torque sharing or compensation is provided by movement of the output gear.

10

The torque compensating gear may also be free to move slightly both in a direction normal to the common plane and/or along the axis of the input rotatable member, as described for example in relation to the output gears 24, 34 in EP 0244263. Another arrangement permitting such translational movements of a torque compensating gear is

15 described below.

The invention in its various aspects, and its further preferred features, are described below with reference to illustrative embodiments shown in the drawings, wherein:

Fig. 1 is a diagrammatic front view of a transfer gear train embodying the invention;

20 Fig. 2 is a diagrammatic sectional view of an automotive transmission incorporating the transfer gear train of Fig. 1;

Fig. 3 is a diagram showing a mounting arrangement for a torque compensating single helical gear that may be used in embodiments of the invention;

Fig. 4 is a diagrammatic section of a further differential unit which may be used in a
25 modification of the Fig. 2 transmission for four wheel drive vehicles, and

Fig. 5 is a diagrammatic section of a planetary differential unit which may be used in a further modification of the Fig. 2 transmission.

Referring to Fig. 1, a transfer gear train 10 for an automotive transmission, comprises an
30 input rotatable member in the form of an input shaft 12 connected to the output of a variable ratio main gearbox (not shown). Input shaft 12 carries an input gear 14 which

meshes simultaneously with a pair of first intermediate gears 16a, 16b mounted on intermediate shafts 18a, 18b journaled in a gearbox casing (not shown). The intermediate gears 16a, 16b mesh with respective further intermediate gears 16c, 16d mounted on shafts 18c, 18d. The further intermediate gears 16b, 16c mesh simultaneously with an
5 output gear 20. In the drawings, the circles illustrate the pitch lines of the various gears shown. For simplicity, the gear teeth are not illustrated.

- As shown in Fig. 2, the output gear 20 is fixed to the input shaft 26 of an axle differential unit 34, having output shafts 36a, 36b for driving respective road wheels (not shown).
10 The differential unit 34 may be of any known conventional kind, for example incorporating slip limiting or lockup means.

To provide even torque sharing between the parallel power paths constituted by the gears 16a, 16c on the one hand and 16b, 16d on the other, the input shaft 12 is mounted so that
15 its end carrying the gear 14 is movable slightly out of the plane containing the shafts 18a, 18b. The bearings 30 may allow pivoting of the shaft 12 about an axis normal to the page (as indicated by the arrows 32) and the shaft 12 may incorporate a splined or other connection for this purpose. Such torque compensating movement is suitable for use with spur gears. If instead the gears 14, 16a, 16b, 16c, 16d are single helical, gear 14 may be
20 mounted to the shaft 12 in the manner described in GB 1434928 to provide the necessary torque compensating movement. Similarly, if the various gears are double helical, mounted in "herringbone" configuration, torque compensation of the resulting compound gear 14 can be as disclosed in EP 0244263.

- Fig. 3 shows a further torque sharing arrangement for use with single helical gears. The compensating movement is provided by mounting gear 14 to shaft 12 via a torque transmitting sleeve 40. Gear 14 is formed as a ring gear having internal helical splines engaging complementary splines 42 on the sleeve 40. Internal helical splines on the sleeve in turn engage complementary splines 44 on the shaft 12. The splines 42, 44 are
30 short and slightly crowned, to allow pivoting of the axes of shaft 12, sleeve 40 and gear 14 relative to each other. The lead and hand of the splines 42, 44 are equal to the lead and

hand of the helical gear teeth 46. This ensures that axial forces on the sleeve 40 and gear 14, arising from the transmitted torque, balance out. With this arrangement, the gear 14 is not only free to pivot slightly out of the plane normal to the shaft 12, but can also translate slightly, both axially and normal to the plane passing through the axes of shafts 18a and 5 18b. This provides improved torque sharing with respect to the mechanism of GB 1434928.

Although in the drawings the torque sharing or compensation mechanism is shown applied to the input gear 14, it could equally be applied to an output or other gear meshing 10 simultaneously with a pair of further gears, the shafts of all three gears being substantially co-planar. For example, the torque compensating movement may be of the output gear, particularly in transfer gear trains providing a step-up ratio.

As shown, the input gear 14 is smaller than the output gear 20. This therefore provides a 15 reduction ratio. The reduction ratio of the final drive differential gearbox 34 may therefore be made smaller. A smaller bevel gear 38 may therefore be used. This results in a much slimmer gearbox 34, further reducing the weights and amounts of materials required, and improving the vehicle ground clearance. Large overall transmission speed reduction ratios may also be achieved, which can be advantageous in high performance 20 vehicles such as Formula 1 Grand Prix racing cars. These currently use servo-operated, clutchless gearshifts, the gearbox having close ratios so as to eliminate the requirement for synchronisers. A large reduction ratio is needed in the transmission final drive. The main gearbox output shaft is close to the ground, so that the drive must be taken upwards to the rear wheels. The arrangement shown in Fig. 2 is suitable for such use. (For clarity, Fig. 2 25 shows the main transmission elements in co-planar configuration. When used in racing car transmissions, the gear train 10 may extend upwardly, i.e. the transfer gear train 10 is rotated from the position shown, relative to the axle differential 34, about the shaft 26, so as to place the shaft 12 at a lower level than the shaft 26).

30 A large centre spacing between the shafts 12, 26 is possible, whilst keeping the size of the gears 16a, 16b, 16c, 16d reasonably small. The transfer gearbox is accordingly compact,

lightweight, quiet, efficient, has low inertia, and is capable of handling high shaft powers. Still further intermediate gears can be added into the power transmission paths, as desired.

It is also possible to eliminate the further intermediate gears 18c, 18d to produce a four gear arrangement in which the gears 18a, 18b mesh directly with gear 20 (the centres of gears 18a, 14 and 18b still being substantially in line to provide torque sharing). However, the gear ratios must then be carefully selected so as to achieve proper meshing of the gear teeth and so as to avoid clashing of gears 14 and 20. Only a limited number of gear ratios and offsets between shafts 12 and 26 are therefore available, which can be found e.g. by numerical means. Some examples are tabulated below.

Numbers of teeth								
Gear 14	Gears 18a, 18b	Gear 20	Gear 14	Gears 18a, 18b	Gear 20	Gear 14	Gears 18a, 18b	Gear 20
5	13	23	15	27	57	15	267	297
5	19	29	15	33	63	30	72	132
5	25	35	15	45	75	30	108	168
5	41	31	15	51	81	30	120	180
5	37	47	15	63	93	30	144	204
5	43	53	15	69	99	30	156	216
5	49	59	15	81	111	30	180	240
5	55	65	15	87	117	30	192	252
5	61	71	15	99	129	30	216	276
5	67	77	15	105	135	30	228	288
5	73	83	15	117	147	30	252	312
5	79	89	15	123	153	30	264	324
5	85	95	15	135	165	30	288	348
10	20	40	15	141	171	30	300	360
10	32	52	15	153	183	30	324	384
10	44	64	15	159	189	30	336	390
10	56	76	15	171	201	30	360	414
10	68	88	15	177	207	30	372	432
10	80	100	15	189	219	30	396	456
10	92	112	15	195	225	30	408	468
10	104	124	15	207	237	30	432	492
10	116	136	15	213	243	30	444	504
10	128	148	15	225	255	30	468	528
10	140	160	15	231	261	30	480	540
10	152	172	15	243	273	30	504	564
10	164	184	15	249	279	30	516	576
10	176	196	15	261	291	30	84	144

Fig. 4 shows a further differential unit 24 for use in four wheel drive (or higher) transmissions. Instead of being fixed directly to the shaft 26, the gear 20 is formed as a ring gear attached to a differential carrier 50 rotatable in a casing 52 of the differential unit 24. The shaft 26 forms one of the output shafts of the differential unit 24. A further output shaft 28 takes the drive to a further pair of vehicle road wheels (not shown), via a further axle differential unit (not shown), similar to unit 34. The transmission arrangement is otherwise similar to Figs. 1 and 2, with the ring gear 20 engaged simultaneously by the gears 16c, 16d (only gear 16c is visible in Fig. 5; in "four gear" transfer train arrangements, ring gear 20 is of course engaged directly by gears 16a, 16b). The differential unit 24 splits the input torque equally between the output shafts 26, 28. Like the axle differential 34, it may incorporate conventional slip limiting and lock-up means. The transfer gear train 10 may be rotated about the shafts 26, 28, from the position shown, to any desired configuration.

15

Fig. 5 shows a modification of the Fig. 4 arrangement, using a planetary differential 60. The ring gear 20 has external teeth for engagement by the gears 16c, 16d (or 16a, 16b) as in Figs. 1, 2 and 4. It also has internal teeth engaged by a plurality of (e.g. three) planet gears 62, which in turn engage a sun gear 64. The gears 62 are journaled in a planet carrier 66, which drives one output shaft 26. The sun gear 64 drives the other output shaft 28. The planetary differential 60 provides an uneven torque split between the shafts 26 : 28 in the ratio

$$d_s + d_p/2 : d_s,$$

where d_s is the diameter of the sun gear 64 and d_p is the diameter of the planet gear 62.

The differential 60 may be provided with otherwise conventional lock-up or slip limiting means, acting between the planet carrier 52 and sun gear 64.

25

CLAIMS

1. An automotive transmission (10, 26, 28, 34) comprising a transfer gear train (10) for transmitting torque between an input rotatable member (12) and an output rotatable
5 member (26) rotating about substantially parallel axes, the transfer gear train (10) comprising an input gear (14) rotatable with the input member (12), an output gear (20) rotatable with the output member (26), and a pair of intermediate gears (16a, 16b) each held simultaneously in mesh with the input gear (14) and transmitting torque to the output gear (20) to provide two power transmission paths;
10 characterised in that the output member (26) drives differential gearing (34) arranged to distribute driving torque to a pair of ground engaging wheels.
2. A transmission as defined in claim 1 characterised in that the input gear (14) is smaller than the output gear (20).
15
3. A transmission as defined in claim 1 or 2 characterised in that one of the gears in the transfer train is made movable in response to the transmitted torque so as to even out power transmission between the two paths.
- 20 4. A transmission as defined in claim 3 characterised in that the torque responsive movement is of the input gear (14).
5. A transmission as defined in any preceding claim, characterised in that a further intermediate gear (16c, 16d) is provided in each power transmission path.
25
6. A transmission as defined in any preceding claim, characterised in that the rotational axis one of the gears (14) in the gear train which is movable in response to the transmitted torque so as to even out power transmission between the two paths, and the rotational axes of two other gears (16a, 16b) in the gear train which mesh simultaneously
30 with the movable gear (14), all lie substantially in a common plane.

7. A transmission as defined in claim 6 characterised in that it comprises spur gears (14, 16a, 16b, 16c, 16d, 20) and wherein the shaft (12) of the movable gear (14) is free to move away from the common plane.
- 5 8. A transmission as defined in claim 6 characterised in that it comprises single helical gears (14, 16a, 16b, 16c, 16d, 20) and the movable gear (14) is free to pivot about an axis normal to the common plane.
9. A transmission as defined in claim 8 or 9 characterised in that the movable gear
10 (14) is mounted to a shaft (12) by a helically splined connection (42, 44), the helix of the splines being of the same hand and having the same lead as the helix of the gear teeth.
10. A transmission as defined in any of claims 6 – 9 characterised in that the movable gear is free to translate out of the common plane and /or along its rotational axis.
- 15 11. A transmission as defined in claim 10 characterised in that the movable gear (14) is mounted to the shaft (12) via a torque transmitting sleeve (40), there being helically splined connections (44, 42) between the shaft (12) and the sleeve (40) and between the sleeve (40) and the movable gear (14).
- 20 12. A transmission as defined in any of claims 1 to 5, characterised in that one of said gears (14) comprises two single helical gears mounted to a common shaft by helical splined connections, the common shaft being coupled to the input (14) or output (26) shaft by a drive connection that allows axial and radial displacement of the common shaft.

1/2

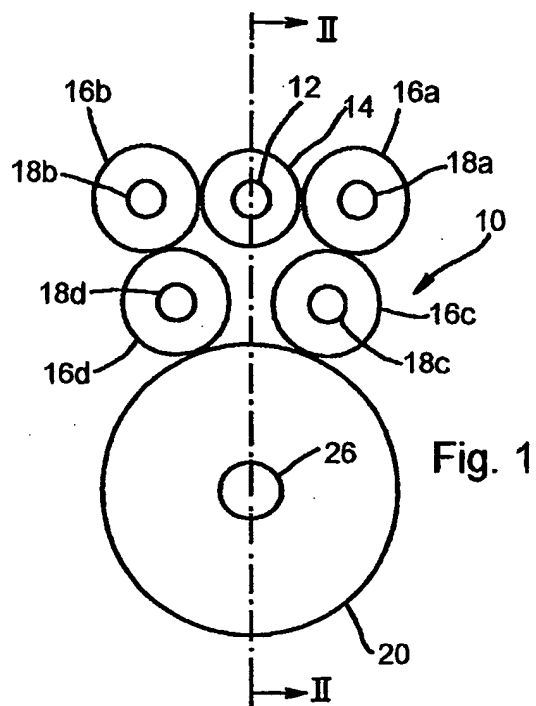
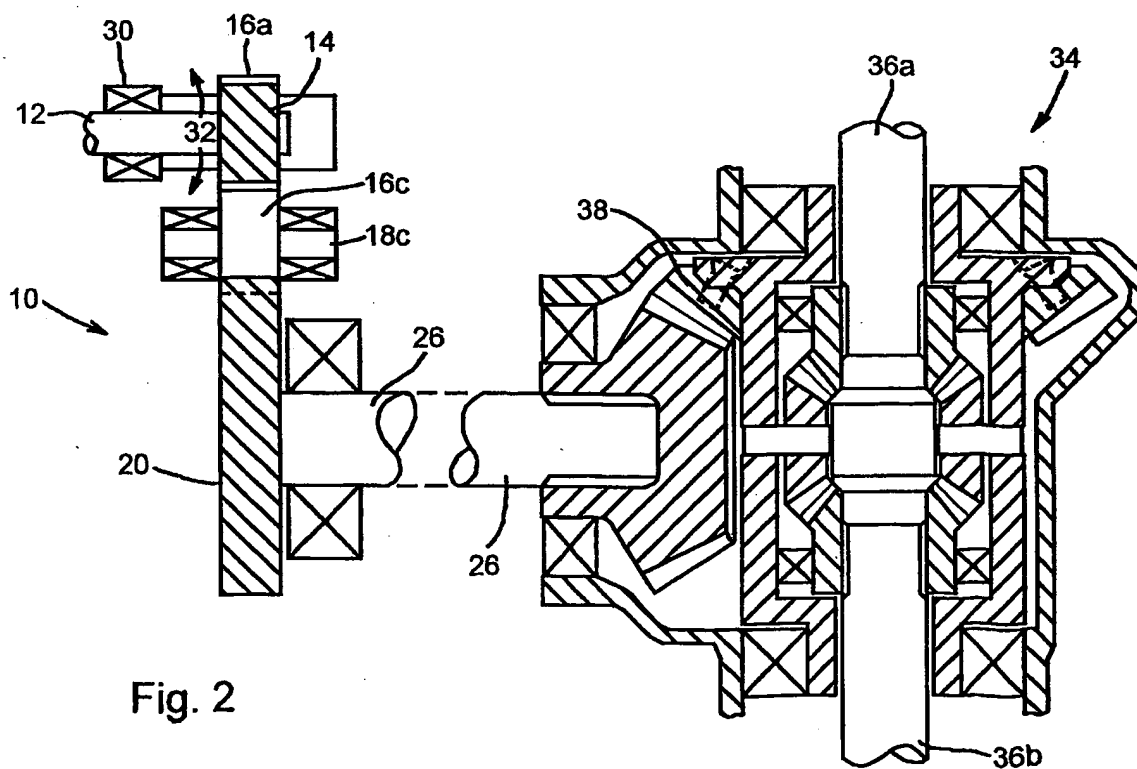
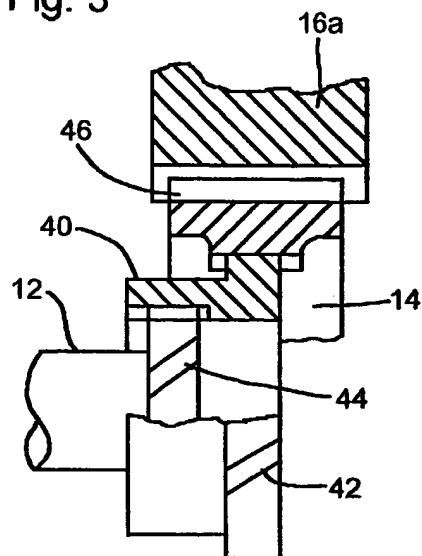


Fig. 3



2/2

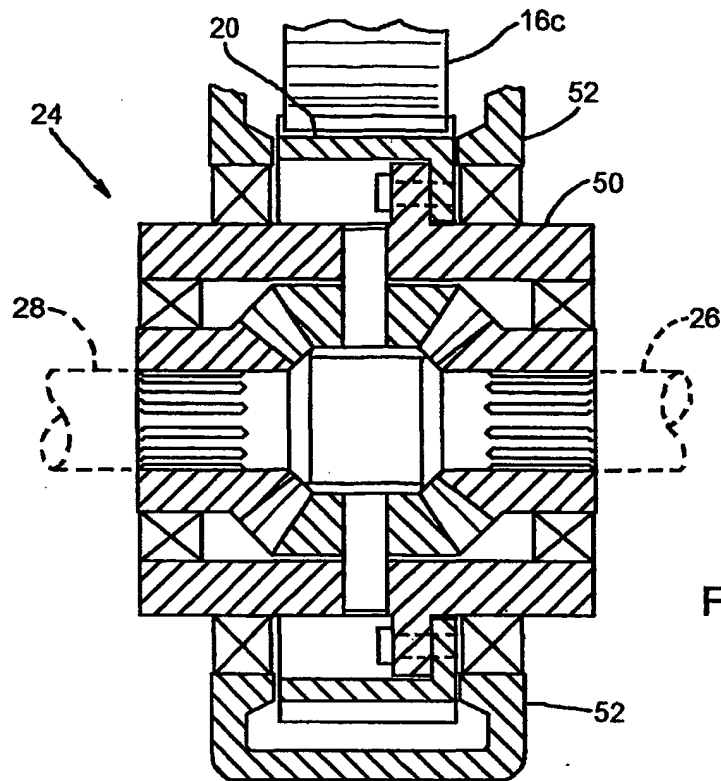


Fig. 4

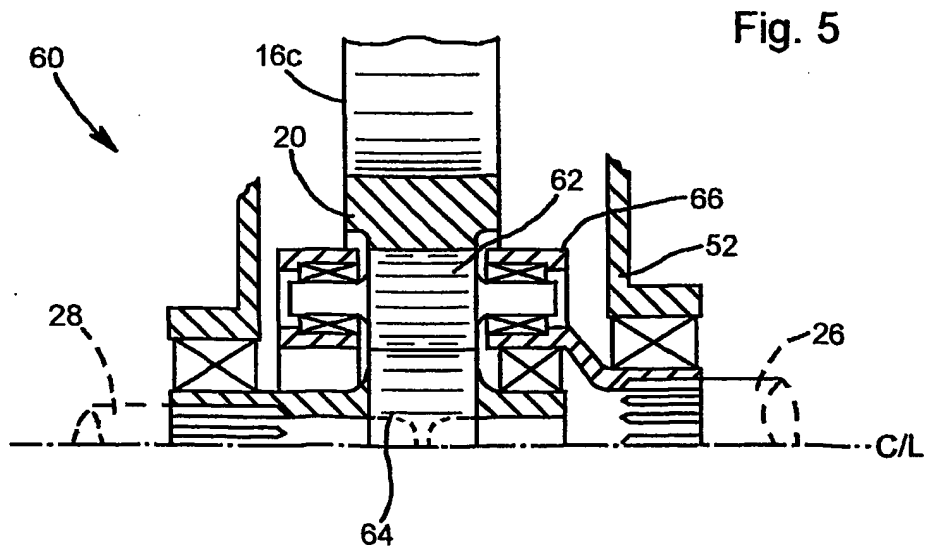


Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 01/02667

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 B60K17/344 F16H1/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 IPC 7 B60K F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 896 775 A (SOUTHCOTT) 27 April 1999 (1999-04-27)	1,2,5
Y	column 2, line 40; figures	3,4,6-12
Y	GB 2 151 327 A (UNITED TECHNOLOGIES CORP) 17 July 1985 (1985-07-17)	3,4,6,7, 10
Y	figures	
Y	GB 660 497 A (WILHELM GUSTAV STOECKICHT) 7 November 1951 (1951-11-07)	8,9,11, 12
	page 2, line 70 - line 80; figure 3	
A	US 4 953 417 A (BAUMGARTEN) 4 September 1990 (1990-09-04)	5
	figures	
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"g" document member of the same patent family

Date of the actual completion of the international search

7 September 2001

Date of mailing of the international search report

13/09/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
 Fax (+31-70) 340-3016

Authorized officer

Goeman, F

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 01/02667

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 695 889 A (DIMOV IVAN IVANOV) 7 February 1996 (1996-02-07) page 1, line 21; figure 2	1,2,5
A	EP 0 244 263 A (PENGILLY ERIC A) 4 November 1987 (1987-11-04) cited in the application figures	8,9,12
A	US 3 889 549 A (FIEUZAL JEAN HENRI ET AL) 17 June 1975 (1975-06-17) figures	7
A	US 3 772 934 A (WARREN R) 20 November 1973 (1973-11-20) figures	8,9
A	US 4 790 210 A (MUELLER ROBERT ET AL) 13 December 1988 (1988-12-13) figures	1
A	US 6 035 956 A (AMSL JOHANN ET AL) 14 March 2000 (2000-03-14) cited in the application figure 2	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 01/02667

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5896775 A	27-04-1999	AU 6209096 A NZ 299180 A AU 706829 B	20-02-1997 19-12-1997 24-06-1999
GB 2151327 A	17-07-1985	BR 8406293 A DE 3445181 A ES 538467 D ES 8507244 A FR 2556436 A IT 1177394 B JP 60139945 A SE 8406253 A	08-10-1985 13-06-1985 01-09-1985 01-12-1985 14-06-1985 26-08-1987 24-07-1985 13-06-1985
GB 660497 A	07-11-1951	NONE	
US 4953417 A	04-09-1990	DE 3809577 A CA 1312223 A FR 2629172 A GB 2218182 A	12-10-1989 05-01-1993 29-09-1989 08-11-1989
EP 0695889 A	07-02-1996	BG 61236 B AT 198229 T DE 69426448 D DE 69426448 T JP 8512383 T US 5682799 A WO 9425778 A RU 2114352 C	31-03-1997 15-01-2001 25-01-2001 23-08-2001 24-12-1996 04-11-1997 10-11-1994 27-06-1998
EP 244263 A	04-11-1987	DE 3765452 D US 4876908 A	15-11-1990 31-10-1989
US 3889549 A	17-06-1975	FR 2221981 A CH 578698 A DE 2406076 A GB 1465782 A IT 1006744 B SE 394502 B	11-10-1974 13-08-1976 03-10-1974 02-03-1977 20-10-1976 27-06-1977
US 3772934 A	20-11-1973	NONE	
US 4790210 A	13-12-1988	DE 3705606 A DE 3765542 D EP 0279889 A JP 63207728 A	01-09-1988 15-11-1990 31-08-1988 29-08-1988
US 6035956 A	14-03-2000	DE 19604730 A DE 59700309 D WO 9728980 A EP 0877672 A HU 9900579 A	14-08-1997 09-09-1999 14-08-1997 18-11-1998 28-06-1999